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FALL CHINCH BUG SURVEY TRIALS IN STANDING CORN

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Very little definite information is available regarding methods of value in accurately determining fall abundance of the chinch bug as a measure of possible intensity of outbreak in the following season. Two criteria have been used: (1) The number of bugs per stalk of standing corn in late fall, and (2) the number of bugs per unit area of bunch grass or other hibernating quarters in late fall and early winter. These two methods are being studied in detail in limited areas in Indiana and Ohio. The results obtained during the fall of 1934 on standing corn are here summarized for the early information of interested workers. These surveys will be compared at a later date with the hibernation survey and subsequent infestation in the same areas.

Chinch bug infestation counts were made by Mr. Benton September 24-28, 1934, in a heavily infested corn field, and on October 1-3 in a moderately infested field, near Lafayette, Indiana. These fields were roughly divided into twelfths, in 4 rows of 3 areas each. Of these, 64 stalks, 16 in each of 4 parallel adjacent rows, were examined in the approximate center of each area or twelfth of the field. The number of bugs, exclusive of nymphs, observed on each individual stalk was recorded separately.

In order to determine the best number and distribution of stalks to use for sampling individual fields, in practical chinch bug surveys, a series of samples of each size and distribution, given in the tables below, was made up from data gathered by the methods previously outlined. No stalk was used more than once in composing any one series of samples. Each sample in a series was therefore completely independent of the others except in size and fraction of field it represented. Samples representing the whole field contained the same number of stalks from each of the 12 areas. Samples representing portions of the field contained the same number of stalks from each of as many areas as were required to compose the designated fraction of the field. In order to show the amount of variation among samples, of the same size and distribution, the standard deviation was computed for each set. From these were calculated the odds that similar samples would fall within definite arbitrary ranges of infestation. In calculating odds, the ranges of infestation suggested by the Illinois workers were used, that is:

Scant - 0 to 3 bugs per stalk
Moderate - 4 to 15 bugs per stalk
Abundant - 15 or more bugs per stalk.

Table 1. Summary of Results, Martin Field, "Abundant" Infestation.

Samples Size	Samples No.	Each taken from-	Bugs per stalk Mean	Bugs per stalk Stand. Deviation	Odds that similar samples will contain 15 or more bugs per stalk	Percentage of similar samples expected to contain 15 or more bugs per stalk
48-stalk	16	whole field	51.10	6.83	18630 to 1	100-
24- "	32	" "	51.10	7.56	9999 to 1	100-
12- "	64	" "	51.10	11.15	363 to 1	99.72
6- "	128	" "	51.20	15.98	84.85 to 1	98.84
24- "	32	$\frac{1}{2}$ field	51.10	12.24	636 to 1	99.84
12- "	64	$\frac{1}{2}$ "	51.10	13.88	214 to 1	99.54
24- "	32	$\frac{1}{4}$ "	51.11	20.35	25.45 to 1	96.22
12- "	64	$\frac{1}{4}$ "	51.11	21.94	19.17 to 1	95.04
64- "	12	1 place	51.10	29.72	7.01 to 1	87.52
12- "	60	1 "	51.45	39.86	4.55 to 1	81.98

Table 2. Summary of Results, Dunwoody Field, "Moderate" Infestation.

Samples Size	Samples No.	Each taken from	Bugs per stalk Mean	Bugs per stalk Stand. Deviation	Odds that similar samples will be included by the range of 4 to 13.9 bugs per stalk	Percentage of similar samples expected to contain 4 to 13.9 bugs per stalk
48-stalk	16	whole field	8.95	1.96	42.03 to 1	97.68
24- "	32	" "	8.95	2.42	23.71 to 1	95.95
12- "	64	" "	8.96	3.08	8.34 to 1	89.29
6- "	128	" "	8.95	4.89	2.22 to 1	68.94
24- "	32	$\frac{1}{2}$ field	8.95	4.95	2.15 to 1	68.25
24- "	32	$\frac{1}{4}$ "	8.95	5.05	2.06 to 1	67.32
12- "	64	$\frac{1}{2}$ "	8.96	5.36	1.83 to 1	64.66
12- "	64	$\frac{1}{4}$ "	8.96	5.51	1.72 to 1	63.24
64- "	12	1 place	8.95	5.28	1.72 to 1	63.24
12- "	60	1 "	8.86	6.33	1.27 to 1	55.95

Due to lateness of season no intensive sampling test was conducted in a field falling into the "scant" range of infestation. A hypothetical case was therefore set up, using the eighteen 12-stalk samples taken from 9 fields in a survey of Tipton County made on October 17. Two 12-stalk samples were taken by Messrs. Benton and Painter in each field, each man examining a single stalk, in each of 12 places, about 50 paces apart on a circuit well into the field. Since all of these samples were very lightly infested it seems reasonable to assume that the results thus obtained are typical of what would be obtained from a similar series of samples taken from a single extremely lightly infested field. We thus have a series of nine 24-stalk samples or a series of eighteen 12-stalk samples for analysis. Results are as follows:

Table 3. Summary of Results, Hypothetical Field, "Scant" Infestation.

Samples: Size	Samples: No.	Each taken from-	Bugs per stalk: Mean	Bugs per stalk: Stand. Deviation	Odds that similar samples will be included by the range of 0 to 3 bugs per stalk	Percentage of similar samples expected to contain 0 to 3 bugs per stalk
24-stalk	9	12 places on circuit of 1/3 field	.245	.259	Better than	100-
12- "	18		.245	.246	10,000 to 1	100-

Best Size of Sample.--The size of sample to be taken from any one field is limited by the time allowable in practical surveys. Since it was found that the examination of 48 to 50 stalks took $1\frac{1}{2}$ to $2\frac{1}{2}$ hours, depending on number of bugs present, this size seemed about the maximum practical for general use. Also, the above trials indicated that representative 48-stalk samples were fairly dependable measures of infestation. The mean infestations with their respective standard errors, computed from the standard deviations of the 24-stalk samples, are: Martin field, 51.1 ± 1.4; Dunwoody field, 8.95 ± .43; hypothetical field, .245 ± .09. It therefore appears that the respective mean infestations in these single-field trials are very close approximations of the true infestations. If so, doubling the standard deviations for 48-stalk samples (see Tables 1, 2, and 3) would indicate that 95 out of 100 single samples of this size will come within about $\frac{1}{2}$ bug per stalk of the true infestation in very lightly infested fields, about 4 bugs per stalk of the true infestation in moderately infested fields, and about 14 bugs per stalk of the true infestation in fields where infestations are in the neighborhood of 50 bugs per stalk or high in the "abundant" range. Samples approximating true infestations thus closely should throw most fields into their proper ranges, and the few remaining fields into the ranges immediately adjacent to where they belong. Furthermore, in actual surveys the figure representing the infestation in a county or other area would be the mean of a number of samples rather than the individual samples themselves, and in such surveys the few individual samples falling in too low a range would tend to counter-balance those falling in too high a range. In view of the above considerations it is concluded that 48-stalk samples are large enough for practical use.

The next question is how much the size of samples from single fields can be reduced without entailing too great a corresponding reduction in dependability. In order to make intelligent comparison of the amounts of variation in the sets of samples of different sizes and levels of infestation, it is first necessary to reduce these to a common basis of measurement. The coefficients of variation, showing what percentage of its respective mean each standard deviation is, were therefore determined for each set. Variation among samples of each size is thus placed on a directly comparable percentage basis. Only sets of samples representative of entire fields were used in computing the following coefficients of variation:

Size of sample	Martin field (Av. 51.1 bugs per stalk)	Dunwoody field (Av. 8.95 bugs per stalk)	Hypothetical field (Av. 0.25 bugs per stalk)
	Percent	Percent	Percent
48-stalk	13	22	---
28- "	15	27	98
12- "	22	34	100
6- "	31	55	---

These coefficients indicate that variation between individual samples increases rapidly as the size of sample or amount of infestation present decreases. However, they also indicate that variation among single samples is not greatly increased by reducing their size to 24 stalks. Considering the opportunity this presents for taking samples from more fields in the time allowable, 24-stalk field samples would appear to be about the optimum size. These coefficients and the data given in Tables 1, 2, and 3 indicate that reduction in size of sample to 12 stalks per field or less would probably reduce dependability of results too much for practical use. Further evidence from test surveys now becomes essential to a determination of the most practical size of sample. See Experimental Survey of Tippecanoe County below.

Method of Taking Samples.--The first question is how closely a sample taken from only a part of a field may approximate the actual degree of infestation prevalent in the whole field. Tables 1 and 2 show that in these trials the variation among individual samples, whatever their size, increased rapidly with the decrease in size of the fraction of field from which they are taken. For instance, in the Martin field 24-stalk samples showed a standard deviation of 7.56 bugs per stalk when taken from all 12 parts of the field, 12.24 when taken from 6 places representative of only $\frac{1}{2}$ of the field, and 20.35 when taken from 3 places representative of only $\frac{1}{4}$ of the field. It is evident that infestation varies greatly in different parts of a field, and that single samples taken from only a portion of a field cannot be depended on for a close estimate of the bugs per stalk present in the whole field. It is therefore concluded that samples must be taken so as to be fairly representative of the area sampled, whether that area is all of a field or only a portion of it.

Experimental Survey of Tippecanoe County.--In extensive surveys, the time-consumed factor would appear to preclude the representative sampling of entire fields. Even the time required for walking throughout entire fields, to say nothing of making the counts, would be almost prohibitive. On the basis of the total time spent in making the counts in the Martin and Dunwoody fields, the time per 48-stalk sample averaged approximately 2 man-hours.

But in practical surveys, is it necessary that samples be representative of whole fields? Would not more dependable results be secured by reducing the size of the basic unit areas sampled and increasing their number per county? Having tentatively determined the size of sample necessary to represent with reasonable accuracy the field or part of field sampled, can we not limit our counts to portions of individual fields or to whatever area is involved in taking 1 or 2 stalks every 50 paces or so on a large enough circuit into the field to give us a 12-stalk or 24-stalk sample? So long as our samples are representative of whatever area is actually covered, can we not ignore fields as entities and think of our samples as representing a part of a county or larger area? For survey purposes we are mainly interested, not in individual

fields, but in the average infestation prevailing in a county or other unit of area. So why not combine a series of such samples from all parts of the county into a composite sample, representative of the county? If this procedure is permissible, how many and what size of samples will be necessary to obtain a dependable county average from such a series?

In order to approximate the answers to these questions a survey was made, October 8-12, of Tippecanoe County by Benton and Painter, each taking a 12-stem sample in each of 90 fields, using the circuit method and counting the bugs present on 1 stalk at every 30 to 50 paces. The county was roughly divided into 3 tiers of 3 areas each, and 10 fields were sampled in each area. Samples each composed of 48 stems from each field would have been desirable, but due to lateness of season and gradual migration of bugs from corn it was necessary to modify the plans and complete the sampling as rapidly as possible. The maximum size of sample from each field was therefore set at 24 stems.

The original single-stalk infestations were tabulated, and the data combined and recombined into sets of 12-, 24-, and 48-stalk samples, each set being representative of the whole county. No figures were used more than once in any series except in the case of the 5-field sets, in which the samples from area No. 5 were used twice, once in making up sets from areas 1, 3, 5, 7, and 9, and once in making up sets from areas 2, 4, 5, 6, and 8. This was done in order to utilize all the available data in a single computation for sets of this size, and, in the case of the 12-stalk samples at least, had little effect on the results since, as shown in the following tabulation, either lot consisting of completely independent samples showed practically the same mean infestation and standard deviation as that obtained when the two lots were combined.

Size of Sample	Areas represented	No. of sets	Mean number of bugs per stalk	Standard deviation
12-stalk	1,3,5,7,9	20	9.75	4.83
"	2,4,5,6,8	20	9.39	4.78
"	above combined	40	9.57	4.81

A comparison of samples and sets of samples of different sizes is given in Table 4.

Table 4. Summary of Tippecanoe County Sampling Trials.

Individual field sample	No. of areas rep. in set	No. of sets	Bugs per stalk Mean	Stand. Dev.	Expectation that similar county samples will fall within range indicated: Odds	%	Range
12-stalk	5	40	9.571	4.811	2.87 to 1	74.16	4.14 to 15
24- "	5	20	9.573	4.685	2.85 to 1	74.03	4.15 to 15
48- " (2 fields)	5*	10	9.572	2.593	14.15 to 1	93.40	4.14 to 15
12- "	9	20	9.555	3.786	5.00 to 1	83.33	4.11 to 15
24- "	9	10	9.555	3.705	4.70 to 1	82.46	4.11 to 15
48- " (2 fields)	9*	5	9.554	2.084	15.89 to 1	94.08	4.11 to 15

*Not having 48-stalk samples actually taken from single fields, this size was made up by combining 24-stalk samples from 2 fields in the same area. But a study of the original data, and also comparison of the county results with those from the Dunwoody field at about the same infestation level,

indicated that the variation between sets of 48-stalk samples taken from single fields would be considerably greater than that between the sets of 48-stalk samples shown in this table, where each sample represented 2 fields.

In analyzing this county survey, the first consideration is the time required per county. As near as this can be estimated from these experiments, the time required for practical surveys would be about as follows:

Size of sample	No. per county	Man-hours
48-stem	9	21
24- "	9	12
12- "	9	7
48- "	5	12
24- "	5	7
12- "	5	4

One man apparently could cover about a county a day, examining nine 12-stem samples or five 24-stem samples by the 50-pace method, although his progress would vary considerably with amount of infestation encountered and other conditions. If he were to examine 48-stem samples it would take him $1\frac{1}{2}$ to 3 days per county, depending on number of samples taken, amount of infestation, size of the county, etc.

The next question for consideration is the size and number of samples per county necessary for dependable results. Table 4 indicates that 12-stalk samples, from 9 places in the county, are about the minimum size and number of samples which might be considered sufficiently dependable for practical survey purposes. Dependability apparently decreases rather rapidly with reduction in the number of samples below 9 but does not increase very rapidly with increase in size of sample above 12. The larger sized samples, however, would probably show to better advantage if a larger number of sets were available for comparison. Furthermore, as explained above, the dependability of sets of 48-stalk samples from single fields is probably considerably lower than shown in Table 4 for sets of 48-stem samples where each sample represents 2 fields. However, there would be no object in taking samples by this latter method in actual surveys.

Dependability of survey results can of course be increased to whatever degree is desired by simply increasing size and number of samples, but it would seem that a size and number of samples giving an estimate within 5 or 6 bugs per stalk of the true infestation, for 83 percent of the time when infestation is in the "moderate" range, as indicated above for nine 12-stalk samples per county, would be sufficiently dependable for practical survey purposes. The results of single-field experiments in Tables 1-3 indicate that the closeness of the estimate would vary with the degree of infestation, being within about 1 bug per stalk of the true infestation when in the "scant" range, within 5 or 6 bugs per stalk in the "moderate" range, and decreasing in accuracy as infestations increased into the "abundant" range. Increasing size and number of samples to 48-stem from 9 parts of the county would increase the time required per county from one man-day to three, and the dependability from 83 percent to about 90 percent. Although it is probable that 24- and 48-stem samples would show to better advantage if a more adequate series of them were available, these trials indicate that a large increase in time would be required in order to attain very much improvement in depend-

ability over that to be expected from nine 12-stem samples per county. The results of the Tippecanoe County experiment give odds of better than 10,000 to 1 that the infestation in corn at the time these counts were made fell into the "moderate" range. Nineteen out of the 20 sets of 12-stem samples taken in this county showed a "moderate" infestation, and the remaining one showed 16.3 bugs per stalk, or only 1.3 bugs above the upper limit of the "moderate" range.

These trials, therefore, would indicate that a set of nine properly representative 12-stem samples taken by the 50-pace-circuit method, or the approximate equivalent of such a set, is adequate to give an estimate of the chinch bug infestation in Tippecanoe County or a similar area to the degree of accuracy necessary for the uses ordinarily made of such information, and that the securing of very much more accurate estimates would involve a much more intensive survey.

Other County Surveys.--In order to obtain data from counties containing different levels of infestation for comparison with future surveys of the same counties by other methods, Benton, Clinton and Tipton Counties were surveyed. A 12-stalk sample was taken by each of 2 men from each of 9 fields distributed over the county, as explained above for Tippecanoe County. Each sample was taken 1 stalk per place by the 50-pace-circuit method, the men keeping together so that the samples were taken from the same areas. The following table shows averages for individual observers and for the counts when combined into a single set of nine 24-stem samples for each county.

Table 5. Results of Trial County Surveys in Standing Corn.

County	Date	Observer	Av. Bugs per Stalk Individual	Av. Bugs per Stalk Combined	Range
Benton	Oct.15 1934	Benton	14.4	13.4	Moderate
		Noble	12.3		
Tippecanoe	Oct.8-12 1934	Benton	9.0	9.6	Moderate
		Painter	7.9		
Clinton	Oct. 10 1934	Benton	2.8	3.5	Scant-moderate
		Luginbill	4.1		
Tipton	Oct. 17 1934	Benton	.3	.25	Scant
		Painter	.2		

Considerable migration of bugs to winter quarters had probably occurred before these surveys were made. Therefore the ranges of infestation indicated above may be too low. It would undoubtedly be advisable to make practical surveys earlier in the fall before much migration has occurred and before much corn is cut, especially in areas where corn cutting is generally practiced. In these experiments counts were made of adults only. Earlier surveys, however, would encounter many bugs not yet in the adult stage and thus involve the difficulties of whether or not to count nymphs, what sizes of nymphs to include with the expectation of their maturing and hibernating successfully, and of making anything like an accurate count or estimate of the numbers present.

Differences between Counts Made by Different Observers.--The above county surveys have involved four different observers. It will be noted

(Table 5) that the individual and combined surveys for each county all fall within the same range of infestation. While it would have been desirable to have had the individual surveys made independently in different fields, we would not have been able to make a comparison of results obtained by different observers if the surveys had been made that way. Also we already had the Tippecanoe County trials to show the variation to be expected among independent sets of samples from the same area.

Dependability of surveys obviously rests first of all on the accuracy of the observations. Counts by different observers may be expected to differ to some extent, especially where there are so many bugs that it becomes necessary to estimate rather than actually to count the number per stalk. In the present experiments the original figures for individual 12-stem samples suggest a tendency for the counts of one observer to be somewhat lower or higher than those of another. In the Tippecanoe County survey, for example, the ten sets of 12-stem samples taken by Benton averaged 9.0 ± 3.5 bugs per stalk and the 10 sets taken by Painter averaged 7.9 ± 4.4 bugs per stalk. Since the average obtained by either observer falls well within the standard deviation of the samples taken by the other observer it is obvious that the difference between the two averages is not significant. That is, the variation due to observer is less than that due to chance, hence it becomes of minor importance.